Noninvasive Evaluation of Cardiac Risk Before Elective Vascular Surgery

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The prognostic utility for predicting cardiac events was determined for dipyridamole-thallium scintigraphy, exercise stress testing (when possible; n = 69) and multiple clinical variables in 100 consecutive patients admitted for elective surgical repair of peripheral vascular disease. After initial noninvasive evaluation, 11 patients were referred for coronary angiography and the remaining 89 patients had surgery without further cardiac studies. Fifteen patients (17%) had a postoperative myocardial infarction, one of which was fatal. Of these 15 patients, 14 had thallium redistribution and 3 had positive ST segment depression during stress testing. Among the many variables tested, the presence of redistribution on serial dipyridamole-thallium images was the most significant predictor of serious cardiac events. All 11 patients who had coronary angiography had both redistribution and multivessel coronary artery disease. Four of these 11 patients died during follow-up and 6 had coronary artery bypass surgery.

It is concluded that dipyridamole-thallium imaging has significant prognostic utility in predicting postoperative myocardial infarction and death in patients with severe peripheral vascular disease, and is superior to exercise testing or clinical variables in determining cardiac risk. The odds for a serious cardiac event were 23 times greater in a patient with thallium redistribution than in a patient without redistribution, strongly suggesting that myocardial imaging may be used as a primary screening test before elective vascular surgery.

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Myocardial infarction accounts for nearly 50% of the morbidity and mortality after peripheral vascular surgery (1–4). Clinical evaluation alone does not accurately detect asymptomatic coronary artery disease nor does it assess the potential risk for additional ischemic events in patients with known disease (5,6). Routine coronary angiography has been reported to demonstrate severe coronary stenoses in 40 to 50% of patients undergoing vascular surgery (5–7), but it is an expensive screening technique and does not provide a functional evaluation of cardiac risk. In an effort to avoid cardiac catheterization in all patients, previous studies have utilized exercise stress testing (8–10) or dipyridamole-thallium imaging (11) to identify those patients who are more likely to have postoperative cardiac complications. However, there are clear limitations noted in these reports.

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Patients selected for vascular surgery cannot always perform an adequate exercise test because of claudication, amputation or other reasons, and this results in a decreased sensitivity of exercise testing for detection of coronary artery disease (8–10). Dipyridamole-thallium imaging was reported (11) to have good sensitivity in a relatively small group of patients who were already suspected of having coronary artery disease.

A noninvasive test that can be performed in all patients and has a high sensitivity for coronary disease could potentially provide an ideal screening test for elective surgery. Accordingly, this report compares the prognostic utility of exercise testing with that of dipyridamole-thallium scintigraphy in patients before vascular surgery, and utilizes only serious cardiac events (infarction and death) during the postoperative follow-up period. The goal of the study was to determine, before surgery, which clinical, exercise and scintigraphic variables would be most helpful in evaluating postoperative cardiac risk. It was hypothesized that the presence of thallium redistribution would be of prime importance in detecting those patients having coronary disease who have potentially jeopardized myocardium (11,12). It was also clear that patients having a very positive preoperative test result would be managed differently by their personal phy-

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sicians. Therefore, this study analyzed two groups of patients based on whether or not cardiac catheterization was performed before surgery.

Methods

Study patients. This prospective study was carried out in 100 consecutive patients who were admitted for elective abdominal aortic or limb vascular surgery at the University of Massachusetts Medical Center from January 1984 to April 1985. During this time, an additional nine patients had vascular surgery without noninvasive evaluation because of scheduling problems. Patients having new or medically unstable angina pectoris as well as a recent (4 to 6 month) myocardial infarction were excluded from the study. In addition, patients were excluded if they had high grade ventricular arrhythmia, decompensated congestive heart failure, severe obstructive pulmonary disease or severe renal disease. All these exclusionary criteria were chosen on the basis of previous work (13) suggesting that patients having these problems are at higher risk for postoperative cardiac complications. All patients gave written informed consent for all procedures.

Thallium scintigraphy (n = 100) and exercise testing (n = 69) were performed in the fasted state 1 to 5 days before surgery. Any patient taking an oral theophylline compound was instructed to stop the medication 36 hours before the imaging protocol because of its direct antagonist effect on a dipyridamole infusion. Exercise testing was not performed in 31 patients because of physical limitations (n = 27) or scheduling conflicts (n = 4). Every patient was interviewed and examined by the cardiology consultation team before and after surgery, and serial electrocardiograms and serum cardiac enzymes were monitored for 2 to 3 days postoperatively. The medical charts were subsequently reviewed independently to establish the incidence of cardiac death or myocardial infarction, or both. Myocardial infarction was defined by both a typical rise and fall in serum enzyme level that was consistent with cardiac necrosis (specifically creatine kinase MB isoenzyme fraction) and the appearance of new Q waves or evolutionary ST-T wave changes on the electrocardiogram (14).

Dipyridamole-thallium scanning and analysis. Dipyridamole-thallium imaging was performed according to a previously described protocol (15) that represents a slight modification of the original description by Gould et al. (16). Briefly, intravenous dipyridamole (Boehringer Ingelheim) was infused into the supine patient at a rate of 0.56 mg/kg body weight over 4 minutes. Three to 4 minutes later, 1.5 to 2.5 mCi of thallium-201 (New England Nuclear) was injected intravenously. The patient remained supine while anterior and 45 and 70° left anterior oblique view images were collected for 7 minutes, each on a dedicated computer system (PDP 11/34, Digital Equipment). Similar views were repeated after 3 to 4 hours. The serial images were qualitatively interpreted by utilizing a previously described scoring system that divided each set of images into a total of nine segments (12,15). All scans were classified as normal or abnormal on the basis of initial segmental perfusion defects, and the delayed image scores defined the initial defects as having redistribution (complete or partial) or no redistribution (persistent defects). Systemic blood pressure and 12 lead electrocardiograms were collected frequently during the first 15 minutes of the imaging protocol. The occurrence of any symptoms during or after the dipyridamole infusion was noted and parenteral aminophylline was available for the treatment of any adverse effects.

Exercise testing protocol. Depending on individual ability to perform an adequate exercise test, each patient was given exercise on either a programmed treadmill (n = 56) according to the Bruce protocol or an arm ergometer (n = 13) utilizing a previously described protocol (9). Each patient had continuous 12 lead electrocardiographic monitoring and blood pressure was determined by arm cuff during each exercise stage. The exercise test was continued until the patient was forced to stop because of claudication, dyspnea, generalized fatigue, moderate angina pectoris, dizziness, high grade ventricular arrhythmia or systolic hypotension. A positive ST segment response was defined as demonstrating horizontal or downsloping depression of 0.15 mV or greater at 80 ms after the J point in any recorded lead during exercise or recovery.

Clinical course analysis. The results of the exercise and thallium studies were available to the attending physicians and on the basis of these results, as well as the clinical evaluation, 11 patients were referred for coronary angiography before undergoing vascular surgery. These patients were analyzed separately from those not having preoperative cardiac catheterization. Significant coronary artery stenosis was defined by a luminal diameter narrowing of at least 50%. An example of a patient study from this group is shown in Figure 1. The remaining 89 patients had vascular surgery as planned without prior coronary angiography even though several had positive imaging results. Most of these patients had intraoperative and postoperative hemodynamic monitoring by insertion of pulmonary and radial artery catheters. Initially (first 6 months of study), attending physicians were not likely to change routine patient care or surgical procedures on the basis of the scintigraphic findings. However, it subsequently became apparent that patients with thallium redistribution were more likely to have more conservative surgical operations and more intensive hemodynamic monitoring.

Statistical analysis. Fisher's exact test was used to determine the significance of differences in the rates of occurrence of cardiac events, and all other comparisons between groups of a single numeric variable were performed by an analysis of variance and appropriate t statistic (17).

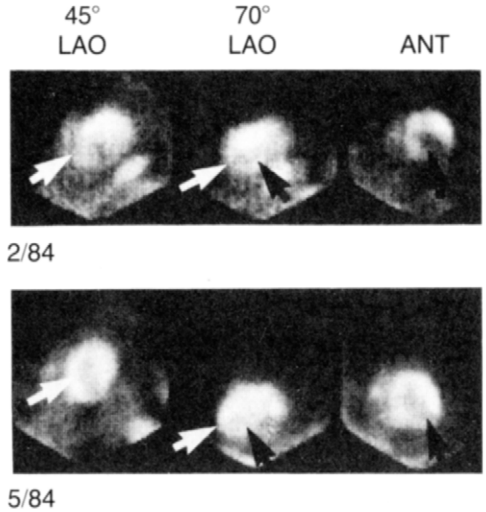

Figure 1. Initial dipyridamole-thallium images in a 71 year old man who had a history of a previous myocardial infarction and an abdominal aortic aneurysm. After the initial scan in February 1984 showed transient defects (**white arrows**) in the anterior and septal walls and persistent defects (**black arrows**) in the inferior and apical walls, the patient had coronary angiography and bypass surgery. A second study in May 1984 showed no transient defects and he then had uncomplicated vascular surgical repair.

All results are expressed as mean values ± SD. In addition, a nonlinear stepwise logistic regression analysis (BMDPLR Health Services Computing Facility) was utilized to determine the statistical value for the prediction of postoperative cardiac events of many clinical, scintigraphic and exercise variables (Table 1). In this analysis, a predictor can be entered into the model at a p value of less than 0.10 and is removed at a subsequent step if the p value is greater than 0.15.

Results

Clinical characteristics and test results. Table 1 shows the clinical characteristics and dipyridamole-thallium scan results of all the patients as well as the exercise test variables in the 69 patients who completed this part of the study. Sixty patients had an abnormal myocardial perfusion scan and 53 (88%) of these patients demonstrated thallium redistribution in at least one segmental defect. In patients having an abnormal scan, the average number of defects was 4.4 from a total of 9 segments per study. Thirty patients experienced some adverse effects during the dipyridamole

Table 1. Patient Features and Noninvasive Test Results

Clinical Variables (n = 100)			
Mean age (yr)	68 ± 9 (SD)	Diabetes	18
Sex	64 male; 36 female	Hypertension	69
History of CAD	51	History of COPD	18
Angina	45	Abdominal surgery	63
History of MI	39	Digoxin	18
ECG Q wave	36	Diuretics	48
History of CHF	10	Beta-blocker	30
History of CABG	20	Calcium channel blocker	8
Claudication	76	Antiarrhythmic agent	12
		Nitroglycerin	21
Dipyridamole-Thallium Scan (n = 100)			
Abnormal scan	60	Mean no. of:	
Thallium redistribution	53	Defects/scan	4.4 ± 1.6
Response to dipyridamole		Redist. defects	2.5 ± 1.5
Any side effect	30	Partial redist. defects	0.7 ± 0.9
ST ↓ > 1.5 mm	16	Persistent defects	1.3 ± 1.6
Chest pain	15		
Exercise Test (n = 69)			
ST ↓ > 1.5 mm	19 (28%)	Total time (min)	5.1 ± 3.4
Chest pain	18 (26%)	Peak heart rate (beats/min)	118 ± 24
Exercise arrhythmia	17 (25%)	% Max heart rate (beats/min)	77 ± 15
Peak rate-pressure product (mm Hg × beats/min)	20,730 ± 5,129		

CABG = coronary artery bypass surgery; CAD = coronary artery disease; CHF = congestive heart failure; COPD = chronic obstructive pulmonary disease; ECG = electrocardiographic; Max = maximal; MI = myocardial infarction; Redist. = redistribution; ST ↓ = ST segment depression.

Table 2. Patient Selection for Cardiac Catheterization Before Surgery

	Cath (n = 11)	No Cath (n = 89)	p value
Mean age (yr)	67 ± 9	71 ± 5	NS
History of CAD	6 (55%)	45 (51%)	NS
History of MI	3 (27%)	36 (40%)	NS
History of angina	6 (55%)	39 (44%)	NS
ECG Q wave	2 (18%)	34 (38%)	NS
Presence of redist.	11 (100%)	42 (47%)	0.001
Mean no. of:			
Defects/scan	5.3 ± 1.6	4.2 ± 1.5	0.06
Redist. defects	3.3 ± 1.3	2.3 ± 1.5	0.03
Persistent defects	1.7 ± 2.1	1.2 ± 1.5	NS
	(n = 9)	(n = 60)	
Total exercise time (min)	5.6 ± 3.2	5.0 ± 3.5	NS
Peak heart rate (beats/min)	118 ± 25	115 ± 15	NS
% Max heart rate (beats/min)	76 ± 12	77 ± 15	NS
ST ↓ >1.5 mm	7 (78%)	12 (20%)	0.01

Cath = cardiac catheterization; NS = not significant; other abbreviations as before.

protocol, including headache, dizziness, angina, nausea or ST segment depression. Intravenous aminophylline was administered after the thallium-201 injections to reverse these effects in 15 patients. No serious complications or cardiac arrhythmias were noted. In contrast, 28% of the exercising patients demonstrated an ischemic ST segment response while achieving an average heart rate of over 75% of maximal predicted rate and a heart rate-systolic pressure product of greater than 20,000 mm-Hg × beats/min.

Coronary angiography. Table 2 presents the clinical, thallium scan and exercise data according to whether patients had cardiac catheterization before vascular surgery. The 11 patients having catheterization had significantly more thallium redistribution and exercise ST segment depression than those not having catheterization. In addition, these 11 patients tended to have a greater mean number of segmental defects per study. Coronary angiography in these patients demonstrated triple vessel disease in nine patients (one also had left main disease) and double vessel disease in the remaining two patients. The average left ventricular ejection fraction was 54 ± 21%.

Cardiac events. Of the 89 patients who underwent vascular surgery without catheterization, 15 had a perioperative myocardial infarction including 1 that was fatal and 10 that were non-Q wave infarctions. Table 3 shows the distribution of clinical, exercise and imaging data based on the occurrence of a cardiac event. Only the presence of either an abnormal scan or thallium redistribution demonstrated a significant difference. Although patients with ST depression and shorter total exercise time tended to have more events, these differences were not statistically significant. No events occurred in the 12 patients who were able to perform more than 9 minutes of exercise, although 4 of these patients had thallium redistribution and 2 had both ST depression with exercise and redistribution. In addition, neither the use of any of the medications listed in Table 1 or the type of surgical procedure had a significant distribution among patients who had a cardiac event.

Regression analysis of predictors of cardiac events. In the 89 patients not having cardiac catheterization, a stepwise nonlinear logistic regression analysis was used to identify those predictors from Table 1 (excluding exercise variables) that had significant prognostic value for postoperative myocardial infarction or death. An additional analysis was also performed in 60 of these patients who also had an exercise test so that the exercise data could be compared with the clinical and scintigraphic results in the same group of patients. Table 4 summarizes the significant findings of these two logistic regression analyses. In the entire group of 89 patients, there were six factors that had significant univariate predictive value for cardiac events, and two other factors were very close to achieving significance. The presence of thallium redistribution was the most significant predictor and was, therefore, entered into the model in step 1. Only the presence of ST segment depression during dipyridamole infusion and a history of diabetes had significant prognostic value in addition to thallium redistribution alone. When these three terms were incorporated into the model, the p value for removal from the model was 0.03 for thallium redistribution but 0.11 for diabetes and 0.13 for ST depression with dipyridamole. Therefore, the increase in prognostic value for these additional factors was small in comparison with the value of thallium redistribution alone.

From the regression analysis, the predicted probability of a cardiac event in patients not having redistribution was 2 ± 2% (1 of 47), but in patients with redistribution it was 33 ± 7% (14 of 42). If diabetes or ST depression with dipyridamole was added to thallium redistribution, the pre-

Table 3. Preoperative Factors for Myocardial Infarction or Death After Vascular Surgery in 89 Patients

	No Event (n = 74)	Cardiac Event (n = 15)	p Value
Age (yr) (mean ± SD)	67 ± 9	67 ± 10	NS
Total exercise time (min)	5.3 ± 3.5	3.6 ± 1.0	NS
Peak rate-pressure product (mm Hg × beats/min)	20,811 ± 5,547	21,995 ± 3,778	NS
Peak heart rate (beats/min)	118 ± 25	118 ± 22	NS
% Max heart rate (beats/min)	77 ± 16	73 ± 11	NS
No. defects/scan	4.2 ± 1.5	4.2 ± 1.6	NS
No. redist. defects	2.2 ± 1.6	2.4 ± 1.1	NS
No. persistent defects	1.1 ± 1.4	1.2 ± 1.6	NS
No. of men	47 (64)	8 (53)	NS
History of CAD	38 (51)	8 (53)	NS
History of MI	28 (38)	8 (53)	NS
History of angina	39 (53)	7 (47)	NS
History of CHF	5 (7)	3 (20)	NS
History of COPD	11 (15)	4 (27)	NS
ECG Q wave	29 (39)	5 (33)	NS
Diabetes	18 (24)	7 (47)	NS
Abnormal scan	35 (47)	14 (93)	0.001
Thallium redistribution	28 (38)	14 (93)	0.001
Dipyridamole ST ↓	5 (7)	4 (27)	NS
Dipyridamole angina	5 (7)	3 (20)	NS
Exercise ST ↓	9/53 (17)	3/7 (43)	NS
Exercise angina	14/53 (26)	1/7 (14)	NS

Figures in parentheses indicate percent. Abbreviations as before.

dicted probability increased to 59 ± 16% (10 of 17). The estimate of the odds ratio or relative risk predicted from this model for a postoperative cardiac event in a patient with thallium redistribution is about 23 times greater than that for a patient without redistribution, and the addition of diabetes or ST depression with dipyridamole increases the risk about 30-fold. Because each odds ratio estimate is adjusted for the effects of the remaining variables, the estimate of risk for thallium redistribution is for subjects who are comparable for the remaining clinical variables. There were no

Table 4. Significant Predictors by Logistic Regression Analysis for Postoperative Cardiac Events

Predictor	Step 0 p Value*	Thallium Redistribution Entered in Step 1 p Value*
A. 89 Patients (15 events)		
Thallium redistribution	0.0009	(0.0009)
Abnormal scan	0.0036	0.8021
Number of redist. defects	0.0049	0.4187
Dipyridamole ST ↓	0.0195	0.0807
Diabetes	0.0838	0.0628
Number of persistent defects	0.0880	0.4896
Dipyridamole angina	0.1043	0.3872
History of CHF	0.1043	0.2198
B. 60 Patients (7 events; exercise data included)		
Thallium redistribution	0.0080	(0.0080)
Total exercise time	0.1059	0.1203
Exercise ST ↓	0.1113	0.1875

*p value $<$ 0.10 is significant to enter model. In Step 0, each predictor is independently evaluated for significance; in Step 1, the program places the most significant predictor into the model and determines the significance of including other predictors into the model. Abbreviations as before.

significant differences in the clinical or exercise variables (including medications and type of vascular surgery) among patients according to thallium redistribution.

In the second regression analysis (Table 4), which included the 60 patients having both exercise and scan studies, only the presence of thallium redistribution was significant at step 0. Although total exercise time and ST depression with exercise were close to achieving statistical significance, no exercise variable was independently significant and none had additional prognostic value once thallium redistribution was entered into the model. Borderline (0.1 − 0.14 mV) ST depression was also included in this analysis and did not achieve prognostic significance.

Clinical outcome. Figure 2 shows the clinical outcome of all 100 patients entered into this study. The left side follows the course of the 89 patients who went directly to surgery; only one patient in this group died. That patient had thallium redistribution, an asymptomatic exercise test with borderline ST depression and multiple postoperative problems including a nontransmural infarction, congestive heart and renal failure and a cerebrovascular hemorrhage. The right side of Figure 2 shows the outcome in the 11 patients referred for cardiac catheterization. Clearly this latter group, which was referred for catheterization on the basis of strongly positive scan and exercise test results, had a worse prognosis. There were four deaths (36%) in this group compared with one death (1%) in the group not having cardiac catheterization ($p < 0.001$). Two patients died after cardiac catheterization: one diabetic patient developed renal failure after angiography and an aortic aneurysm ruptured during the resulting delay in surgery; the other patient developed severe ischemic pump failure and was not a candidate for coronary bypass surgery. A third patient had a cerebrovascular accident 24 hours after catheterization and has not had further therapeutic intervention. There was one fatal myocardial infarction after coronary bypass surgery and another death after vascular surgery in a patient who did not have prior coronary bypass surgery. Finally, one patient had a non-Q wave myocardial infarction after a combined surgical procedure for coronary bypass (left main and three vessel disease) and abdominal aorta resection.

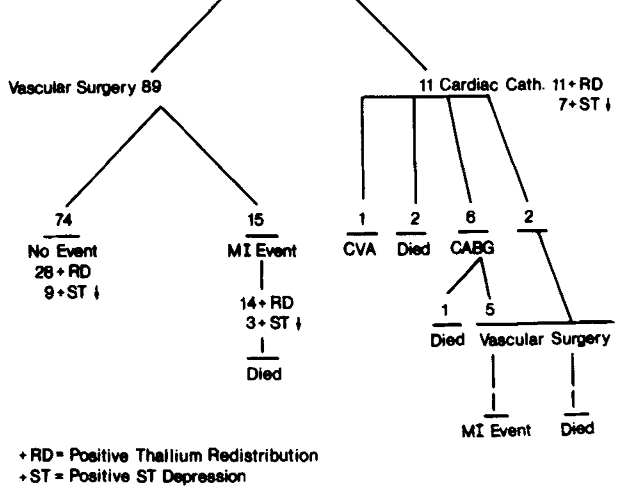

Figure 2. Summary of the follow-up of the 100 patients entered into this study. CABG = coronary artery bypass grafting; CVA = cerebrovascular accident; MI = myocardial infarction.

Discussion

Our goal was to compare the prognostic value of exercise testing and dipyridamole-thallium imaging in patients admitted for elective vascular surgery. The results indicate that scintigraphy is superior. We have also demonstrated that adequate cardiac risk assessment can be done noninvasively and that preoperative cardiac catheterization can then be directed only to those who might benefit most from coronary bypass surgery. It is also important to discuss the ability of dipyridamole-thallium imaging to meet the criteria of an ideal screening test in patients with peripheral vascular disease. Specifically, does this scintigraphic technique alone provide sufficient clinical information to assess cardiac risk, or should it be combined with other factors for optimal results?

Cardiac risk evaluation (exercise versus dipyridamole-thallium imaging). Although cardiac events are the most significant postoperative complication in patients undergoing vascular surgery, how to determine an individual's cardiac risk profile remains a difficult clinical decision. Several studies (5–7) have documented by coronary angiography the relatively high prevalance of coronary artery disease in this surgical group, but it is not feasible to recommend that every preoperative patient undergo cardiac catheterization. The obvious alternative choice would be a noninvasive screening test that had very high sensitivity for coronary disease and also yielded good prognostic information. This screening test must have high sensitivity because of the relatively high prevalence rate and the potentially lethal nature of coronary disease in the patient group.

Exercise stress testing has been previously reported (8–10) as a preoperative screening test, but it lacks a high sensitivity and some patients simply cannot perform any type of adequate (75 to 85% of predicted maximal heart rate) exercise protocol. The relatively older age in this type of patient group as well as the high incidence of hypertension and use of cardiac and diuretic medications all contribute to the reduction in sensitivity and prognostic utility of exercise testing. The fact that a prognostic value for exercise indexes was not observed in our study further supports the impression that exercise, which was frequently submaximal in this group, was not particularly sensitive to detect ischemia. In contrast, a recent report by Boucher et al. (11) demonstrated that dipyridamole-thallium imaging had a sensitivity of 100% for postoperative ischemic events in patients with peripheral vascular disease. These encouraging results were tempered by the relatively small patient group studied, the exclusion of patients without a history of coronary disease and the lack of a comparison with a less costly noninvasive test (electrocardiographically monitored exercise). However, this original description did provide important confirmation of an earlier analysis of the predictive power of dipyridamole-thallium imaging in patients with a known history of coronary disease (12) and our results strongly support their findings in patients having vascular disease.

Scintigraphic findings and specific patient characteristics. Our study was designed to compare exercise and imaging techniques in all preoperative patients regardless of past history, and establish, if possible, a diagnostic protocol that would adequately assess cardiac risk. Consequently, our most important clinical observation was that thallium redistribution was the best predictor among all clinical, exercise and scintigraphic variables for cardiac events. Furthermore, there were no clinical or exercise variables that were significantly correlated with redistribution. Therefore, the presence of redistribution selected patients who were otherwise not readily identified as having increased cardiac risk. Fourteen (7 of whom had no history of coronary disease) of 15 patients who had a postoperative cardiac event demonstrated thallium redistribution, and the odds of an event in a patient with redistribution were about 23 times greater than in one without redistribution.

It is important, however, to consider the specific characteristics of this patient population before establishing any overall recommendations from our data. As evaluated by the number of abnormal thallium scans, the incidence of coronary disease in our 100 patients was 60% and is similar to that in reports that utilized coronary arteriography to detect stenoses (5–7). The incidence of cardiac events in patients who had vascular surgery without coronary arteriography was 17% (15 of 89) and is the same as that of a recent study (11) in which events were observed in 8 (17%) of 48 patients. The mortality rate in our study was 1% (1 of 89), which is similar to that of studies (6,7) that utilized coronary angiography and bypass surgery as routine patient screening, but lower than values (5 to 15%) observed in previous studies from this institution (9,10). This decrease in postoperative mortality may be explained by the referral of our high risk patients for preoperative cardiac catheterization. A decrease in mortality might also be due to a better identification of patients with potentially ischemic myocardium who benefited from hemodynamic monitoring and more cardiac precautions both during and after surgery. Clearly, the scintigraphic results were occasionally utilized by the patients' personal physician to alter routine operative procedures, which does not necessarily limit the overall interpretation of prognostic value. Rather, it suggests that proper scintigraphic identification of higher risk patients can result in lower mortality because of better clinical management. Although cardiac events remain a prominent complication after vascular surgery (1–4), this study was limited to the analysis of the initial hospitalization for vascular surgery and events occurring after discharge were not included. Further investigation will be required to determine and document any long-term risk in patients having thallium redistribution and no initial postoperative cardiac events.

Clinical implications. The fact that the results of the noninvasive studies were clinically utilized by referring physicians is obvious when one analyzes the group of patients having coronary angiography before vascular surgery. All of these patients had thallium redistribution (typically in multiple segments) and many also had ST depression during exercise. Unfortunately, this small preselected group had a relatively high incidence (45%) of myocardial infarction or death, or both. This was a high risk group of patients who frequently experienced cardiac events during invasive diagnostic or therapeutic interventions. In contrast, a large low risk group was best identified by the absence of thallium redistribution even when the perfusion scan was abnormal (having only a persistent defect). Finally, there was also a group of patients who had an intermediate risk that was characterized by the presence of thallium redistribution (typically of smaller size than that in the high risk group) and who were also likely to have a negative exercise test. This last group could be further categorized as having a higher risk when the occurrence of diabetes and ST depression with dipyridamole was noted in patients with thallium redistribution.

Before outlining a summary recommendation from our data, it is important to note that approximately two-thirds of the patients going directly for vascular surgery had at least one scan segment demonstrating thallium redistribution and did not have a cardiac event. Boucher et al. (11) noted the same findings in half of their patients. Therefore, these two studies show that the absence of thallium redistribution predicts a very low risk for cardiac events, whereas its presence greatly increases cardiac risk. However, thallium redistribution is not a specific marker for such events because surgery can be safely performed in patients with coronary disease when appropriate precautions are taken. In this study, patients having cardiac catheterization averaged more than three defects per scan showing redistribution, but there was no statistical difference in the extent of redistribution among patients not having catheterization who had a cardiac event after surgery. Consequently, those patients showing

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a less extensive degree of thallium redistribution are still at increased risk, but additional factors may be required to evaluate their individual profile.

Specifically, if the thallium scan is normal or shows no redistribution, the cardiac risk is relatively low and routine surgical procedures should be employed. In contrast, patients with a severe degree of thallium redistribution (more than three of nine segments) and additional factors such as diabetes, ST segment depression with dipyridamole or during exercise (if clinically warranted) should probably 1) have coronary angiography and appropriate myocardial revascularization before vascular surgery, or 2) be managed more conservatively in regard to their peripheral vascular disease. Patients who have a less severe degree of thallium redistribution, have no additional risk factors and are able to demonstrate good exercise tolerance (>9 minutes) may proceed to surgery with a relatively low risk when appropriate cardiac monitoring is utilized both during and after their operation. Clearly, further investigations employing such a vigorous screening protocol and obtaining long-term follow-up should now be initiated.

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